

# IPRO 341: Design and Global Market Analysis of a Tool Cabinet

Sponsored by: Versatility Tool Works and Manufacturing



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## **Abstract**

IPRO 341 is in its third semester as a sponsored IPRO at Illinois Institute of Technology. The sponsor, Versatility Tool Works, recently began creating tool cabinets. This IPRO was developed to help better the tool cabinet, create a new outlook on the design, and test the current system the sponsor is using.

## **Background**

The sponsor of IPRO 341, Versatility Tool Works (VTW), is a company specializing in producing precision tooling and sheet metal components. Initially in 1972 when the company was established, it was a tool and die operation. Now, it has expanded as a company that produces a diverse product line. The company's most recent endeavor, is manufacturing industrial tool cabinets.

The previous semesters analyzed the cabinet designed by VTW at that time. Both semesters recommended some changes to increase the cycles the drawer could withstand. These improvements included shot-peened slides, Accuride

slides, and using a harder material. The previous semesters work showed promising results, which encouraged the sponsor to continue the sponsorship for another semester.

Since this IPRO is a continuing IPRO, the objectives change slightly from the previous semester. The sponsor has two main objections they would like to fulfill one in the area of design and another in the area of analysis. The first object was to test the existing cabinet that Versatility Tool Works produces. The second object was to design a new cabinet with innovative features.

## **Objective**

The sponsor, VTW, set objectives at the beginning of the semester. These objectives included testing current slide designs with 550lb and designing a new and innovative tool cabinet. Furthermore, when the slides fail, new slides would be designed and tested with the same weight of 550 lbs. To address these objectives, the tasks were broken down for manageability.

### Testing Slides

- Simulation Test
  - Simulated Cabinet Use
- Material Tests
  - Rockwell Test
  - Force Test
  - Tensile Test
  - Stress Calculations

### Product Development

- Brainstorming
  - Group
- Research
  - Competitors tool cabinets
  - Technology that can be implemented in tool cabinet features
- Tracking system
  - Technology implementation
  - Compatibility with tools
  - Expenses
- Conference with sponsor
- Final development of tool cabinet features
  - Drawings and Computer Animated modeling
  - Benefits of additions

## **Methodology**



it failed after 3450 cycles on the second test removing the locking mechanism. Although there was a significant difference whether the locking mechanism was used, the sponsor wanted to keep using that mechanism. So, the testing got another failure result after 3400 cycles by changing the position of rig with the locking mechanism as our suggestion was accepted.

The design team followed a plan similar to the Gantt chart. However, what they did at the beginning of the semester was focusing on unlimited research and brainstorming in order to find reasonable features so that it was unknown how much time would be needed. However, after developing all the idea that they got through research, it took short time to have final designs.

As a result, the specifics of the methodology used to push the team to make their schedule and generate the results changed with the project. Additionally, the extra possible objective was dropped due to a lack of available working hours to follow the steps of whole schedule without sacrificing the results of the other objectives we worked on.

### **Team Structure and Assignments**

The team was composed of two separate teams, the design team and the testing team. However, the design team had certain group members specifically working on the tracking system. The other members worked on all other features discussed. The testing team worked together to complete the tests and develop the analysis. Each team worked independently to complete the objectives and came together to share ideas. There was a coordinator who connected the two teams. Along with that connection, every week, the teams would meet to share and discuss ideas and progress.

#### Coordinator

Hyejin Park, *Mechanical Science and Engineering*

- Worked on keeping the teams in contact
- Produced Gantt Chart
- Developed the project plan

#### Testing Team

Jeffery Bart, *Mechanical and Materials Engineering*

- Contributed to drawer re-design
- Failure mode observations and insight
- Material properties and issues
- Critical design issues and concerns

Mark Ende, *Aerospace and Mechanical Engineering*

- Worked extensively testing drawer
- Helped design future sliding frame

- Helped develop idea to reduce the moment
- Lead testing team contact with VTW

Shahmeer Khaliqudina, *Electrical Engineering*

- Was part of testing the cabinet and analyzing the data
- Visited VTW to make cabinet more competitive
- Tested cabinet with and without the locking mechanism
- Revised the tool cabinet sent by VTW and researched about it

Jae Lee, *Applied Mathematics*

- Conducted a variety of tests such as physical tests, hardness test, and tension test and took measurement
- Analyzed deformation results
- Participated in group discussion
- Conducted mid-term and weekly presentation
- Reassembled testing machine to implement a new design

Raihan Rahman, *Electrical Engineering*

- Performed testing, and took measurements
- Analyzed results and brainstormed to come up with ideas to improve the current drawer performance
- Brainstormed and reverse engineered the tool cabinet from the competitor
- Found out the anomalies in the machine setup
- Disassembled and reassembled the machine and drawer setup with utmost accuracy
- Visited Versatility Tool Works twice

Saad Sarvana, *Mechanical and Aerospace Engineering*

- Team Leader
- Performed physical property tests of materials for analysis and comparison.
- Brainstormed effective modifications for improvement.
- Conducted test cycles on drawer to obtain lifetime of tool cabinet.
- Analyzed deformation on drawer guides between intervals of test cycles.

Design Team

Sara Cantonwine, *Mechanical and Materials Engineering*

- Co-Team leader
- Researched current tool cabinet designs and features
- Contributed ideas to make the cabinet “next generation”
- Brainstormed designs for different features
- Participated in discussions with sponsor to decide on what features to direct focus
- Visited sponsor to see the situational use of the tool box and the tools that it was storing

Erica Pauley, *Mechanical Engineering*

- Co-Team Leader
- Brainstormed about new tool cabinet features
- Researched competitors tool cabinets
- Developed new tool cabinet features
- Participated in discussions with the sponsor

Arence Gowe, *Mechanical Engineering*

- Researched different methods of tool tracking
- Found samples of tool tracking system
- Researched cost of tracking system components
- Created an interface for the tracking system

Thomas Hotz, Mechanical Engineering

- Create CAD assembly of the tool cabinet
- Contributed ideas to make a competent tracking system that utilizes aluminum bar-coding
- Research current designs and explored ideas for a “next generation” tool cabinet
- Visited Versatility Tool Works to ask questions and discuss objectives

Andrew Kitaka, IT Management

- Tool tracking flow chart
- Graphical User Interface Design

## **Budget**

The team did not have many costs for this semester. Most of the equipment for the testing team was provided by the sponsor, VTW. The design team's samples of new features were purchased by the IPRO. These included; LED lights, magnetic reed switches, and aluminum barcodes. Also, a caliper was needed to continue testing and analysis on the slides, and this was also purchased by the IPRO. Travel expenses to and from the sponsor, Versatility Tool Works, were paid for through the IPRO.

## **Code of Ethics**

A nondisclosure agreement was signed at the beginning of the project, by the request of Versatility Tool Works. This agreement detailed the rights of all work performed for VTW. Furthermore, the nondisclosure agreement verified the privacy of the property of VTW that was seen on its premises. Lastly, it ensured confidentiality of all past, current, and future VTW designs.

While doing research and implementing ideas, any copyright infringement was avoided. Any ideas and developments made are owned by the sponsor, VTW. Furthermore, there were good contributions to the common objective. Whenever

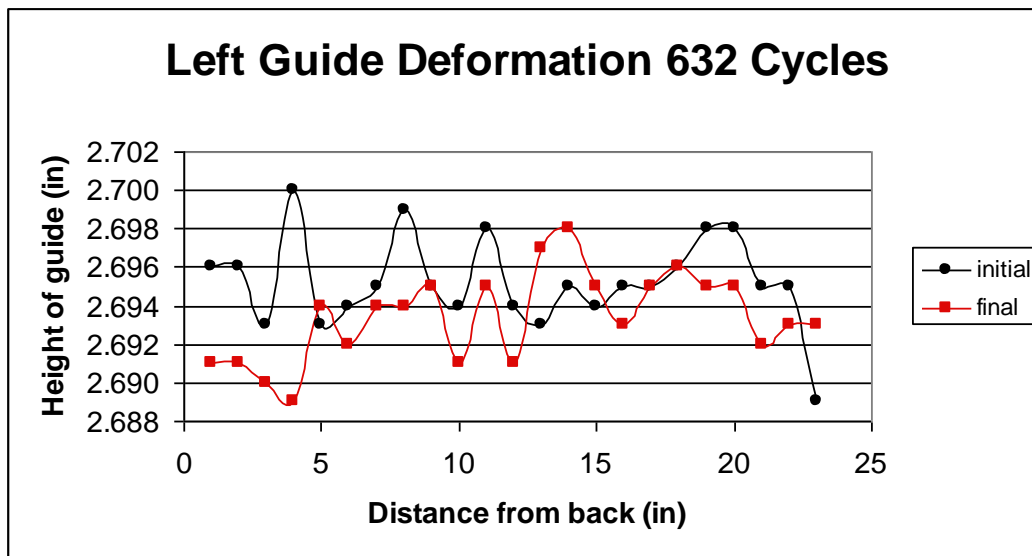
possible, advice was well received from team members, faculty advisors, and/or audience.

For continuity, the same guide of ethics, The Seven Layers of Integrity by June Ferrill, was consulted.

## Results

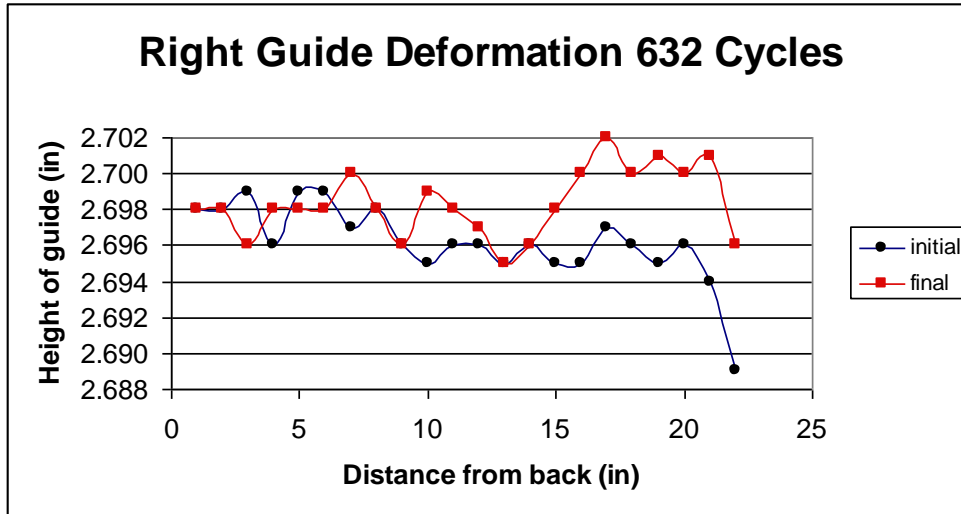
### Testing team

The testing began with the modified initial design of the tool cabinet which consisted of thicker and harder drawer guides with an increased load of 550 lbs. The failure of the design was established at 632 cycles due to the locking mechanism causing the drawer to pivot. When the drawer pivoted, the load became concentrated on the outer edge of the left drawer slide causing enough deformation to prevent proper functioning of the drawer. Figures 1 and 2 show the deformation at failure for the left and right guides respectively.



**Figure 1** The original height of the left guide in test 1 is shown in black, measurements were taken at one inch intervals. The read line depicts the height of the left guide at the time of failure.



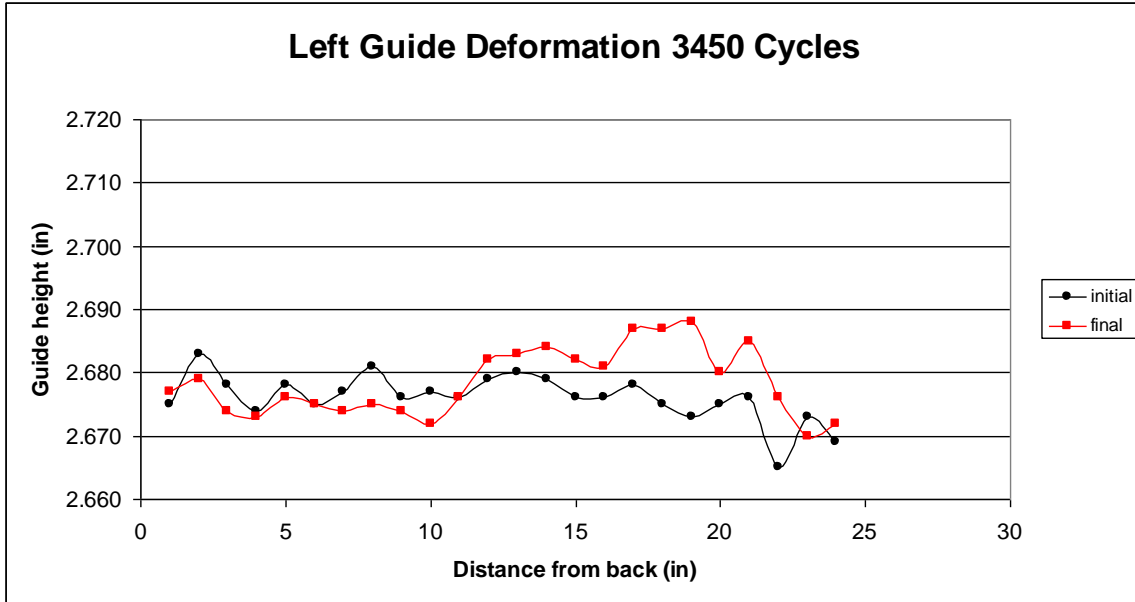


**Figure 2** The original height of the right guide in test 1 is shown in black, measurements were taken at one inch intervals. The red line depicts the height of the right guide at the time of failure.

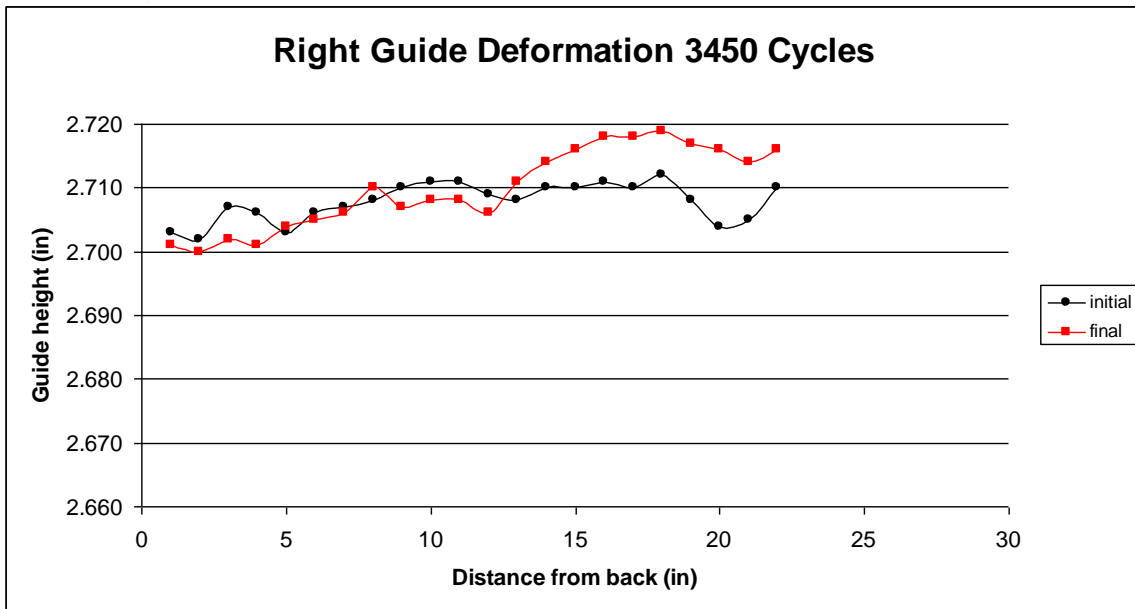
As Figure 2 shows, the region that experienced the most deformation is seen on the right rail between 14 and 22 inches from the back. It is in this region that the drawer reaches full extension, and the full load is supported by a single roller bearing on both the left and right side. In this region, the right guides only deformed around 0.008 inches. The 632 cycles to failure was nearly double that obtained in the summer semester with the thinner guides. This shows that the change to thicker guides made of Cor-10 was a step in the right direction.

The second test was launched with minor adjustments to the drawer handle, reinforcement of the frame under the drawer, and the removal of the locking mechanism.

The testing reached 3450 cycles, but was ended early due to an improper testing rig setup. It became apparent that the machine used to simulate the operation of the drawer was actually supporting some of the load at full extension. After a few simple tests, it was determined that the testing machine was supporting around 120 pounds at full extension. It was also discovered that the sides of the testing rig were not perfectly square. It is important to note that the incorrect setup was also used for a portion of the previous summer semester. This fact allowed a comparison to still be made between the deformation data obtained during the summer semester to the data obtained this semester. Figures 3 and 4 show the deformation at failure for the left and right guides respectively.



**Figure 3** The original height of the left guide in test 2 is shown in black, measurements were taken at one inch intervals. The red line depicts the height of the left guide at the time of failure.

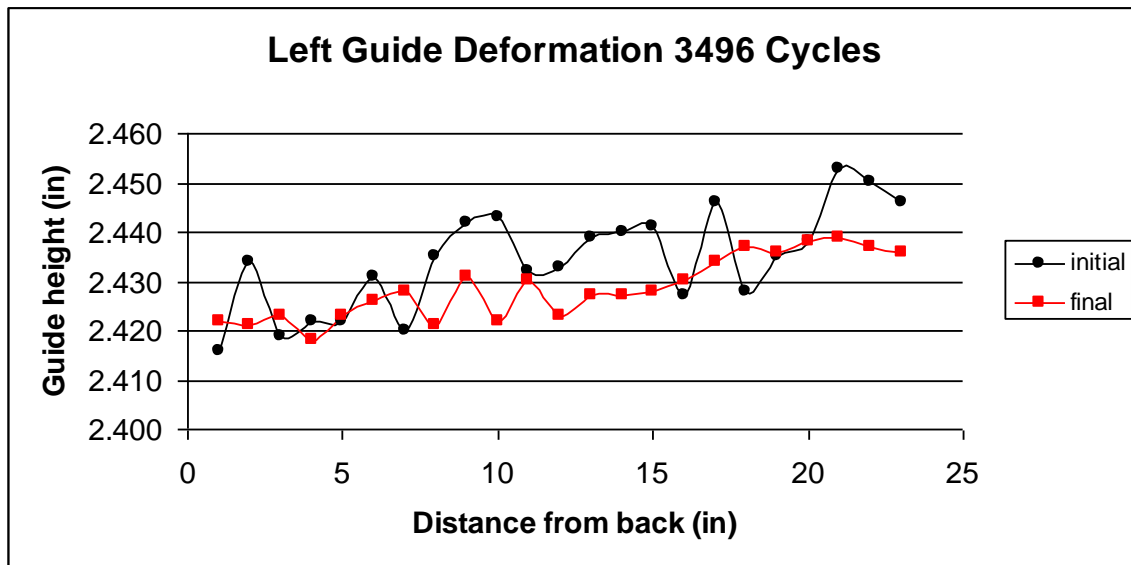


**Figure 4** The original height of the right guide in test 2 is shown in black, measurements were taken at one inch intervals. The red line depicts the height of the right guide at the time of failure.

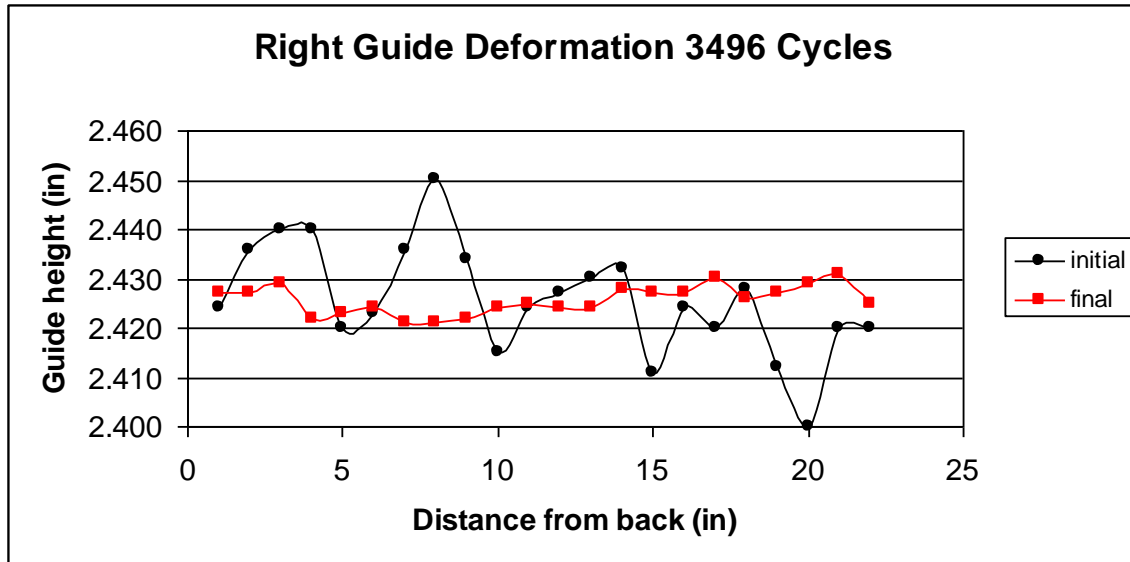
Despite the improper setup, important information was still obtained. Figures 3 and 4 once again showed that the main region of deformation was found to be between 14 and 24 inches from the back. Again this is the area where the load is supported by only one roller bearing on each rail. This in effect becomes a point load on the guide causing greater deformation. As expected the higher number of cycles resulted in more deformation. Deformation was once again

seen on the outer edge of the 's' glides. The deformation on the 's' glides was smaller than in test one with the locking mechanism engaged. Both observations resulted in significant design changes being made for the third trial.

A second iteration of the design was established. To address the issue of the guide deformation, angle brackets were installed. The width of the 's' glides was also shortened. By removing the material from the 's' glides, the point of contact of the roller bearing was moved in closer to the drawer reducing the bending moment. The entire testing rig was re-squared, and the testing machine was lowered so that it no longer bore any of the load at full extension. Clearance adjustments were also made on the entire testing cabinet structure to start the next testing. By the request of VTW, the locking mechanism was reengaged, and the load was reduced to 450 pounds. Failure occurred after 3494 cycles. Figures 5 and 6 show the deformation at failure for the left and right guides respectively.



**Figure 5** The original height of the left guide in test 3 is shown in black, measurements were taken at one inch intervals. The red line depicts the height of the left guide at the time of failure.



**Figure 6** The original height of the right guide in test 3 is shown in black, measurements were taken at one inch intervals. The red line depicts the height of the right guide at the time of failure.

Both Figures 5 and 6 show a reduction of deformation in the region where the load is supported by a single roller bearing on each side. This indicates the effectiveness of the angle brackets. After 500 cycles, the center roller bearing on the left side of the sliding frame broke down and required replacing. The left 's' glide again proved to be the point of failure. After 3496 cycles, the 's' glide had bent up nearly 0.08 inches. The most deformation appeared in the exact same region that was seen in test 1 when the locking mechanism was also engaged. After evaluation, it was determined that the major deformation was the result of the locking mechanism causing the frame to pivot once again, and the fact that the roller bearing broke down. At failure the sliding frame also showed some warping in the cross bars.

The next step is to increase the strength and stiffness of the sliding frame. A stiffer sliding frame should reduce the pivoting motion induced by the locking mechanism. Stiffening of the frame can be accomplished by using thicker material for the cross bars and increasing their width.

Design Team  
*Rotating Cabinet:*  
 What makes this feature both futuristic and functional is that it is not seen in current designs,

and it could increase the longevity of the drawer and drawer guides. It achieves this by utilizing a turn table within the drawer. This would allow a user to only open the drawer a fraction of the length because it can be rotated it to find the tool needed for the job. The fraction of length decreases the moment on the guides, which in theory should increase the life of the guides. The drawbacks on this feature are that it does not utilize all the space with the drawer and balance of tools on the turntable may need consideration.

QuickTime™ and a decompressor are needed to see this picture.

*The pictures show two different rotating cabinets. One that would be used to hold the dyes and the other would be used to hold blade. These are two types of tools that these cabinets will hold.*

### *Lighting System*

Many manufacturing environments are not always well lit. Therefore, a lighting system within the drawers was developed. A strip of LEDs would be contained in a housing above the drawer. When the drawer is opened, the housing containing the LEDs would rotate to direct the lights towards the drawer. The lights would turn on when draw opens. The current design calls for magnetic reed switches to turn on the lights when the drawer opens, but this aspect can be modified to better fit the drawer use.

*These are the LED lights being used for this device. They are able to be cut for easy fitting into each drawer size.*

QuickTime™ and a decompressor are needed to see this picture.

QuickTime™ and a decompressor are needed to see this picture.

*These are the magnetic reed switches which are currently being considered for a part of the implementation of this feature.*

### Extras

#### *Detachable Tool Box*

This feature is seen in many tool cabinets today because of its ability to fit in large drawers and is able to hold small, frequently used tools. In an aim to be futuristic, the design team explored and considered ways to design this feature to be able to carry blades and dies that Versatility Tool Works uses. The potential designs brought on flaws that outweighed the benefits. Thus, the design team came to the conclusion that existing toolboxes are more than competent.

QuickTime™ and a  
decompressor  
are needed to see this picture.

*This is a design of a possible detachable toolbox.*

#### *Scratch Resistant Coating*

Scratch resistant coating would extend the life of the tool cabinet. Different paints or texturing could be implemented. A texture similar to a refrigerator was thought to be the most cost effective because scratch resistant paints, car paints, are very expensive. This was discussed with the sponsor as a possibility. They already powder coat their current design, so adding texture would be something they could look into.

### *Push-to-open Drawers*

QuickTime™ and a decompressor are needed to see this picture.

This feature was conceived from household drawers having this feature. It was seen as being futuristic and researched confirmed that now other tool cabinets on the market have this feature. Therefore, this feature would set VTW apart from its competition.

### *Tracking System*

#### *Barcode System*

Through research, the design team decided to use anodized aluminum barcodes as the building block for a sufficient and effective tracking system. Barcoding allows a tool to be scanned in and out of a computer program that can record the activity of a tool. With proper training and organization, this tracking system could be flawless. One problem with this system is the fact that a tool can be taken out without being scanned. To solve this problem and add to the overall intelligence of the cabinet, proximity sensors can be placed within drawers. These sensors allow the computer to know when a tool is picked up or placed. Proper practice will need to be stress because each tool has a designated spot.

### **Obstacles**

#### Testing

The main obstacle encountered by the testing team was obtaining time in the testing lab. The lab used for testing was the only available space with the proper power source to run the testing rig. Regular classes were held in the lab in which the testing rig was located. The noise of the testing interrupted the classes, so testing had to be discontinued. The remedy to this obstacle was obtaining a class usage schedule for the lab. This allowed the establishment of smaller testing teams of two or three people that were able to work around the class schedule. Many times, testing needed to be performed during the lunch break, on weekends, and Friday mornings when the class was unoccupied.

#### Design

When researching and design features, there was always a problem with feasibility. Although the designs were innovative and imaginative, they had to be possible in order for the sponsor to be able to use them. Not only was there a problem with the possibility of single feature, but the features in compliance with each other.

The cabinet had a certain dimensions that were previously used. These dimensions would like to be conserved, generally, throughout the design. There

were some spatial restrictions that effected decisions of which features were used in the final design.

The previous semesters had problems with the compatibility of the tracking system and the tools. This semester, different options were researched and the most compatible was used.

With any new product, cost is an issue. Although some of the features are a bit expensive, the goal was to design the features to the best quality.

## **Recommendations**

### Testing:

The locking mechanism caused some problems while testing the drawer. To modify it, the rubber blocks could be replaced with roller bearings. This would decrease the friction in the locking mechanism. The locking mechanism should also be used on both sides to have even wear on both slides.

The crossbars should be strengthened as well. The crossbars being stronger will add to the strength of the entire sliding frame. This will increase the cost effectiveness of the overall cabinet. The recommendation to improve the sliding frame involves increasing the thickness and width of the cross bars. This should in effect stiffen up the entire sliding frame and help prevent some of the pivoting caused by the locking mechanism.

Moving forward it is evident that the angle brackets beneath the guides must be included in future cabinet designs. The importance of the angle brackets will become much more apparent when even higher numbers of cycles are reached before failure. The reduced bending moment on the 's' glides must also be incorporated in future designs. Coupled with the reduction in load, the 's' glides used in test 3 showed significant improvement over those used in test 1. When the locking mechanism was engaged, the reduced bending moment 's' glides resulted in over five times the number of cycles achieved in the first test. Again it must be noted that the original testing rig was setup improperly. Despite this fact, an increase of nearly 3000 cycles is still significant. The warping of the cross bars of the sliding frame seen in test 3 also illustrates the fact that the sliding frame needs to be strengthened.

### Design

Continue the development of the tracking system. Customer feedback should be researched on this tracking system to determine how well it fits the customers needs. Also, the tracking system needs to be simplified because VTW's need is not for a large amount of tool components.



Develop some of the features, while researching to find new ones. The light system idea should be furthered more because of VTW interest in this particular feature.

The cabinet should be precisely designed with correct dimensions. So, it can be put into a stress analysis program.

### **References**

McMaster-Carr

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Alibaba.com for the magnetic reed switches

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